

No. 10.— *New Cephalopods from the Fayetteville Shale.*

BY CAREY CRONEIS.

THE cephalopods described here constitute a portion of the palaeontologic collection from the Fayetteville formation made during the academic years 1923–1925, while the writer was a member of the Department of Geology of the University of Arkansas. The formation takes its name from the city of Fayetteville, the site of the University, in whose environs it is well exposed. The bulk of the collection is now the property of the University of Arkansas Museum, but the holotypes of the species described in this paper belong to the Museum of Comparative Zoölogy. The writer is indebted to Dr. Percy E. Raymond for numerous suggestions and criticisms in this study, to the University of Arkansas for its coöperation in making the collection, and to Mr. E. B. Dane for his assistance in the preparation of the plates.

Before describing the fossils themselves, it may be well to discuss briefly the formation in which they occur. The Fayetteville shale of Arkansas and Oklahoma is, in general, a black, fissile, carbonaceous shale usually overlain by the Pitkin limestone, which marks the top of the Mississippian in this region. It rests either disconformably upon the Boone limestone or conformably upon the Batesville sandstone, where the latter is present. Not infrequently the Pitkin has been removed entirely by pre-Pennsylvanian erosion, and in this case the Fayetteville is overlain by the Morrow series of early Pennsylvanian age. More rarely, as in northeastern Oklahoma, the Morrow also is wanting and the Fayetteville is succeeded by the Winslow formation, which is regarded as the local equivalent of the Pottsville.

Although black shales constitute the bulk of the formation, there is, near the top, a prominent sandstone member, known as the Wedington, and which may be mapped over considerable areas in the central and western portions of the Fayetteville exposure. The shale above the Wedington reaches a maximum thickness of seventy feet, but usually it is much thinner and is often wanting. It is neither so dark nor so fissile as the shale beneath the sandstone, and some thin fossiliferous layers of limestone are found interbedded with it. The lower shale is black in color, but weathers to sticky red and yellow clays. Near its base it contains numerous concretions of clay ironstone or siderite which are usually extensively cut by calcite veins to make septaria.

These are often so numerous that they make up approximately continuous septarian layers. A thin limestone at the base of the formation is particularly rich in fossils, and it has yielded several new genera and species which have been described by G. H. Girty (*Annals N. Y. acad. sci.*, 1910, **20**, no. 3, pt. 2). This limestone, which is quite widespread in the Fayetteville region, has not been seen east of the Eureka Springs quadrangle, but to the west it becomes more and more prominent until in Mayes County, Oklahoma, it reaches a thickness of 50-100 feet. Here Snider (*Bull. 24, Okla. geol. surv.*, 1915, p. 27-35) has described it as the Mayes formation.

The Fayetteville has been observed as far north as Fairland, Oklahoma, sec. 15, T. 26 N., R. 29 E., whereas its southernmost exposure is four miles northeast of Gore in the same state in sec. 20, T. 13 N., R. 21 E. The easternmost outcrop of the formation known to the writer is in sec. 35, T. 12 N., R. 5 W., which is a few miles southeast of Batesville, Arkansas. Westward it extends to sec. 2, T. 17 N., R. 19 E., on the eastern bank of Neosho River in Oklahoma. Thus the formation outcrops over an area which in its extreme dimensions is approximately eighty miles north and south by some two hundred and twenty-five miles east and west. Its north-south exposure, however, is usually confined to a belt which is roughly coincident with the lower slopes of the northern face of the Boston Mountains.

In this area the Fayetteville is never wanting, but its thickness varies from as little as ten to about four hundred feet, with extremes of thickness often geographically close together. The formation will probably average close to one hundred feet in thickness, but the chances for error in such an approximation are high and must be considered. The variations in thickness are due to deposition on an irregular surface, whose unevenness was the result in part of erosion, and in part due to structural features.

The fauna of the Fayetteville is abundant and diversified. It has attracted the attention of a number of writers, but it has never been worked out in detail. Previous workers, however, have generally agreed upon the Chester age of the sediments, which at different times have been correlated with the Kaskaskia (Ulrich, *Prof. paper 24, U. S. G. S.*, 1904, p. 24) and Birdsville (Ulrich, *Bull. Geol. soc. Amer.*, 1911, **22**, pl. 29) formations of Illinois, and with the Caney shale of Oklahoma (Girty, *Bull. 377, U. S. G. S.*, 1909, p. 10). Weller, according to a verbal communication to Snider (*loc. cit.*, p. 39), believes that the Fayetteville is probably to be correlated with the Okaw formation of the Chester section in the Mississippi Valley. Girty (*Bull. 593,*

U. S. G. S., 1915, p. 25), however, although recognizing the general equivalency of these beds with some of the typical Chester formations, is inclined to the view that the upper Mississippian of northern Arkansas belongs to a different faunal province than the northern Chester, and that it is impossible to combine the two into a standard time scale. The present writer defers expressing his opinion on the matter until the faunal studies are completed.

Annulated, orthoconic cephalopods are common in a sandy limestone which appears in the stratigraphic position of the top of the Wedington. Coiled forms are also known from this horizon, which is best developed in the vicinity of Fayetteville, and where the Wedington is apparently thinner and more calcareous than usual. The cephalopods described below, however, are from the lower shale of the formation, a part of the Fayetteville which the older geologists regarded as being totally devoid of fossils. More recent writers have recognized the presence of a poorly-preserved pelecypod fauna, and diligent search has revealed several localities where at least average molluscan fossils may be obtained.

ACTINOCERATIDAE Saemann.

RAYONNOCERAS, gen. nov.

GENOTYPE: *Rayonnoceras solidiforme*, sp. nov.

The generic term *Rayonnoceras* is here proposed for a group of cyrtochoanitic cephalopods related to *Actinoceras* and others of the Actinoceratidae, to which family it obviously belongs, but which differs from existing genera in a number of particulars.

Generic description.—Orthoconic Actinoceratidae with camerae completely filled by a uniform organic deposit secreted by the rayonnettes of the endosiphuncle, which terminate at the outer shell of the animal rather than at the outer margin of the siphuncle. Siphuncle large, solid throughout, and strongly corrugated longitudinally, except on the ventral side.

RAYONNOCERAS SOLIDIFORME, sp. nov.

Plate 1, fig. 1–4, 6; Plate 2, fig. 4, 5.

Specific description.—The holotype has a length of 564 mm., a greatest diameter of 145 mm., and a diameter of 45 mm. at the posterior end of the incomplete specimen. The greatest siphuncular diameter

increases from 15 mm. at the posterior end to 43 mm. at the anterior extremity. These figures indicate that the siphuncle increases in diameter nearly, but not quite, as rapidly as the conch itself. The rate of expansion of the shell is approximately 1 mm. in diameter for 6 mm. in length, indicating an apical angle of about nine degrees.

The siphuncle, which is conspicuously ventrad in position, is composed of nummuli whose greatest diameter is approximately twice the length, the largest nummulus being 43 mm. in diameter and 21 mm. in length. The plane of separation between successive nummuli makes an angle of eighty-two degrees with the longitudinal axis of the siphuncle, and in general the diameter at the septal necks is one half the greatest nummular diameter. The nummuli are strongly corrugated longitudinally, except on the ventral side, four to five corrugations occurring in the space of 1 cm.

The septa show a concavity which is approximately one and a half times the length of the adjacent nummulus. The false septa, which join the nummuli a little above their middle (on the dorsal side) reach the outer shell practically in conjunction with the next anterior, true septum, hence their concavity is greater, being equal to the length of two nummuli. There are seven septa per diameter below the point of diametral measurement, or six septa above, which is to say that, on the average, five camerae occur per diameter. The camerae are all filled with a uniform organic deposit (p. 345).

The shell is marked by fine girdling striae which are nowhere continuous enough to determine their course about the conch. The sutures show broad, gentle, but distinct lateral lobes, but their nature on the ventral side is obscured by the crushed condition of the shell.

The siphuncle and its fillings.— Each nummulus of the siphuncle is divided externally into an anterior and a posterior portion by a line which circles it approximately in the plane of greatest diameter, but which is distinctly orad of the true median position on the dorsal side. This line represents the contact of the rayonnettes of the endosiphuncle with the siphuncular wall. One of the nummuli was broken in two along this plane, which is seen to be nearly smooth on the fractured surface, although faintly grooved in a radial fashion. This fact suggests that the double membrane making up the verticillations about the endosiphuncle approached a two-walled disk in structure, and was only prevented from becoming one in effect because the membranes were in contact in some places. This idea is also substantiated by the fact that the line which roughly halves the nummulus is, in the unbroken example, seen to be alternately single and then double. In

the nummuli which have weathered free from the specimen, there may be seen also a longitudinal line crossing the vertical line mentioned above approximately at right angles. It appears on both the ventral and dorsal sides of the nummuli, and in section is seen to divide the siphuncle into halves.

The septal necks, which are very short, are adnate to the posterior portion of the nummuli. The involution of the wall of the siphuncle, which appears at the septal necks, is narrow longitudinally, yet its depth is about one fourth the greatest diameter of the nummulus. The inner portions of the depression are directed slightly apically. The imaginary plane of separation between successive nummuli is so inclined as to give the appearance of alternation of annulations in the longitudinal section, the ventral sides of the nummuli being anteriorly in advance of the dorsal. The eccentricity of the siphuncle mentioned under the specific description, although real, is accentuated by the crushed and flattened condition of what appears to be the ventral side of the shell.

In *Rayonnoceras*, as in *Huronia* and *Actinoceras*, the interior of the siphuncle was filled with calcareous organic deposits, which began to form around the inner margins of the septal necks. With the formation of additional layers the deposits became reniform or lunette-like in longitudinal section, the concave portion being the point of contact with the septa. As the lunettes of successive septal necks grew they tended to meet along a line which is anterior to the median plane of the nummulus on the dorsal side, but which is almost exactly in the plane on the ventral side of the siphuncle (Foerste, *Contrib. Mus. geol. Univ. Mich.*, 1924, 2, no. 3, p. 43). Actually the lunettes are separated by verticillated rayonnettes which have their axis in the endosiphuncle, and which divide the nummuli approximately in halves. The double membrane previously mentioned was, no doubt, the organ secreting the calcareous deposits. The triangular spaces between the outer margins of adjacent lunettes and the inner margin of the annulation are also filled with organic deposits, as is the space between the four lunettes in the center of each nummulus. These deposits, although not exactly amorphous, do not show the uniformity of structure exhibited by the lunettes.

The fillings of the camerae.— In the longitudinal section each camera has a doubly septate appearance, being divided into a posterior and an anterior portion by a pseudoseptum which extends from the median plane of the nummulus to the shell of the animal. These false septa are continuations of the double membranes of the rayonnettes. The

pseudosepta are ordinarily represented by two closely-spaced lines with small triangular projections extending out into the camera on either side; but in some cases the membranes have been pushed together so that but one wavy line may be seen. Apparently, during life, many thin membranes extended out from each pseudoseptum to the true septa on either side, but were not developed in the area adjacent to the siphuncle; or, at least, they were much less prominent there.

The deposition of stereoplasm, or calcareous, organic material, in each camera began simultaneously on the inner sides of the two true septa limiting the chamber. On each a thin layer of uniform thickness was deposited, which extended from the shell of the animal along the septum two thirds of the distance to the siphuncle. The second layer was deposited upon the first, but overlapped it on the end toward the siphuncle in such a way as to become normal to the septum. Every successive layer was deposited in the same manner, so that each on its inner margin bent over the former to touch the septum; and, since the camerae become more constricted toward the shell, each layer was diagonally truncated at its outer margin by the pseudoseptum. Thus, in each camera, deposition took place on both sides of a "V"-shaped opening whose apex was on the pseudoseptum and which opened out toward the nummulus. As more layers of stereoplasm developed, their inner margins moved closer to the septal necks and the apex of the open space migrated toward the siphuncle. Thus the double membrane was finally enclosed in solid material everywhere, but in that limited area close to the nummulus, where the deposits do not show the uniformity of structure which they exhibit farther out toward the shell.

The calcareous material adjacent to the siphuncle is darker than the other deposits of the camerae, and it was evidently deposited later. It is possible that it was formed after the death of the animal by the infiltration of the fine muds in which the shell was buried. On the other hand, there is evidence to support the idea that it also was secreted by the animal. A close examination shows that the deposit is not entirely devoid of organic structure; and that in several camerae double membranes extend on either side of the pseudoseptum out to the true septa, thus crossing the dark material in a longitudinal direction.

Due to the crushed condition of the shell on the ventral side of the siphuncle, the deposits here are not regular, but are composed of numerous fragments of shell-like material intimately cemented together in a

darker matrix. In the longitudinal section the septa are seen to be crushed inward in an anterior direction, and while they are broken and faulted, they ordinarily may be traced for some distance. The light shell-like material so prominent in this area is seen to have identically the same structure as the darker stereoplasm dorsad of the siphuncle, and was deposited on the septa in exactly the same fashion. In some cases a septum and its layers of stereoplasm have fractured as a unit, but more often in the crushing the deposits have become separated from the septa.

The deposition of stereoplasm was at first uniform on all sides of the siphuncle. With the secretion of each additional layer, however, the ventral side was called upon to support more and more weight. In response the animal secreted the ventral stereoplasmic layers more thickly and rapidly, which may account for their lighter color. In spite of this reinforcement of the septa, the shell was crushed while the camerae were still relatively open. After this flattening of the ventral side of the animal, deposition in the uncrushed portions of the camerae went on to completion as described above. The material deposited in the ventral area subsequent to the crushing was no different from the deposit secreted in the camerae adjacent to the dorsal side of the siphuncle. Although the outer shell of the animal is very much crumpled in the flattened zone, it is nowhere seen to be fractured. This is perhaps the more remarkable because of the fact that the shell is extremely thin, almost always being under 2 mm. in thickness.

Comparison with other genera and species.—So far as the writer is aware, the genus *Rayonnoceras* is represented by the largest specimens of orthoconic Carboniferous cephalopods known from North America. The holotype of *R. solidiforme* (see also the description of the holotype of *R. fayetterillensis*) has a known length of 564 mm., and, if the apical angle remains constant, a reconstructed posterior length of 225 mm. The fossil is still septate at the anterior known portion, so that *at least* the length of the body-chamber must be added. If we conservatively estimate the length of the living chamber as being equal to one third the length of the septate portion of the shell, the reconstructed conch has a length of three feet six inches.

The only other Carboniferous cephalopod comparable to the Fayetteville specimens in size is *Actinoceras giganteum* (Sowerby) from the red limestone of Castle Espie, County Down, Ireland, which McCoy (Carboniferous fossils of Ireland, 1844, p. 11) describes as sometimes attaining a length of four feet. *A. giganteum* is the same as *Orthoceras gigantea* described by Sowerby (Min. Conch., 1818, p. 81)

and *A. simmsii* figured by Stokes from the same horizon. Stokes (Trans. Geol. soc. London, 1837, p. 708), however, gives the length of *A. simmsii* as being only two feet.

Actinoceras pyramidatum McCoy, also from the Carboniferous of Ireland, has some points of similarity with *R. solidiforme*, but the rate of enlargement is greater, the endosiphuncle is larger, and the camerae are not solid, though they are filled to some extent by deposits. In addition, the rayonnettes number but three or four rather than being practically continuous, and the corrugations of the siphuncle are not interrupted on the ventral side. In *A. raughanianum* Girty (Bull. 377, U. S. G. S., p. 48) we might expect to find a close resemblance to *R. solidiforme* since it is found at approximately the same horizon (the Caney shale of Oklahoma) and does have some superficial features in common with the Fayetteville form, including size. But here again the camerae of *A. raughanianum* are only partially filled by organic deposits, the apical angle is less than in *R. solidiforme*, the sutures are straighter, the shell not only is thicker but lacks striae, and the concavity of the septa is less.

Points of similarity between *R. solidiforme* and many of the Actinoceroids might be cited, but the differences always resolve themselves into dissimilarities in the deposits of the camerae and in the rayonnettes of the endosiphuncle. Grabau (Palaeontologica Sinica, 1922, p. 73, 74), however, has described a number of Chinese Actinoceroids from the Machiakou limestone of Ordovician age (Black River), whose septal thickening may perhaps be explained as analogous to the fillings of the camerae in Rayonnoceras. Under the generic description of the group, he says:—

“In practically all of the specimens of Actinoceras from the Machiakou limestone, a striking thickening of the septa by stereoplasm or organic deposits of carbonate of lime has taken place, so that the camerae are more or less completely filled by this calcareous deposit. Complete filling is rare, but has been observed in some cases, while in others the thickening has proceeded only far enough to fill about one half of the camera. The thickening is most generally produced by addition of lime to the upper surface of the septum, but in other cases it appears to be added to the under side as well. It is however possible that this appearance is deceptive, and due to the irregularity of the septum. * * * That this lime-deposit is of organic origin, *i. e.* deposited by the animal which occupied the shell, is beyond question, for only by such an origin can the uniformity of the deposit be explained. That it was formed on successive floors of the living-chamber, *i. e.* that each deposit was formed before the next covering septum was built, seems to me also evident, for there is absolutely no indication that the camerae were in subsequent communication with the animal, the small tubuli of the siphuncle notwithstanding. . . .”

and later (p. 78), under the specific description of *A. richthofeni* Frech, he says:—

“In some cases the stereoplasm is included between the septum and a pseudo-septum next in front. * * * Again there may be a slight deposit of stereoplasm both on the upper and under sides of the septum, but this is generally irregular, especially on the under side, as if the septum had been broken. Thickening by stereoplasm on both sides of the septa is indicated in Frech's figure of the type, but I have not seen any specimen in which the thickening is as regular as is shown on the right side of his figure. A fragment which I refer to this species * * * has the camerae nearly filled with stereoplasm, the septa appearing out of position, ending apparently against the nummuli. This would give the appearance of Frech's figure, if we assume that the septa are pseudo-septa, and that true septa occur in the midst of the stereoplasm deposit. Of this there is however no indication. In fact, the septa are strongly bent backwards, so as to rest for a space against the upper or frontal surface of the next preceding nummulus. If a deposit of stereoplasm exists on the under side of the septum it could hardly be explained otherwise, than by assuming its formation to have taken place after the formation of the septum, in which case there must have remained some organic connection between the camera and the animal.”

That there was an organic connection between the camerae and the animal in *Rayonnoceras solidiforme* is clear; and if we assume that such was also the case in *Actinoceras suanpanoides*, *A. richthofeni*, *A. tani*, and especially in *A. coulingi*, the deposits of stereoplasm in these forms may be explained more easily and rationally. The newly established genus, *Stereoplasmoceras*, also from the Machiakou limestone of north-eastern China, and from which Grabau suggests that *Actinoceras* may have been derived, is, as its name implies, characterized by organic deposits in the camerae. In a number of its species stereoplasmic thickening on the under side of the septa has gone on to an embarrassing degree, if we attempt to explain the formation other than by deposition by membranes in the camerae.

In 1861, Owen (*Palaontology*, p. 102) suggested that the tubes, or foramina (rayonnettes) of the *Actinoceratidae* may have served for the passage of blood-vessels to the living membrane of the septal chamber. This suggestion, certainly disregarded, and perhaps overlooked, is at last substantiated in *Rayonnoceras*. Since in this genus the animal maintained communication with its septal chambers, it is fair to presume that allied forms may have done likewise in greater or less degree; particularly when they exhibit septal thickening which cannot be explained satisfactorily otherwise.

Three remarkable preservations of the endosiphuncle and its rayon-

nettes in Niagaran Actinoceroids are introduced for comparison in Plate 2, fig. 2, 3, and 6. They represent hitherto unfigured specimens from the Walcott collection in the M. C. Z. In these early forms the rayonnettes of each nummulus are few in number rather than being so continuous as to be disk-like, as they are in Rayonnoceras. These specimens show marked differences from one another in the method of diverticulation of the tubuli, and in Figure 3, the foramina are seen to extend through the siphuncular wall where that part of the animal has been preserved. That there were membranes in the camerae of all of these forms is probable, but by no means certain; but a lack of evidence for their presence must not be construed as proof of their absence.

Rayonnoceras solidiforme had the ability to re-cement fractures in its shell as evidenced by the mended portion of the conch shown (Plate 2, fig. 4). This is a property which has long been recognized in other Nautiloids; but the explanation of the process of repair would be greatly simplified if we assumed that the animals maintained membranes in the camerae.

Locality and horizon.—*Rayonnoceras solidiforme* is represented by a single specimen from the N. $\frac{1}{2}$ of the NW. $\frac{1}{4}$ sec. 29, T. 15 N., R. 28 W. at Durham, Arkansas. Its exact stratigraphic position was fifteen feet above the top of the Boone limestone in the lower shale of the Fayetteville formation.

RAYONNOCERAS FAYETTEVILLENSIS, sp. nov.

Plate 1, fig. 5; Plate 2, fig. 1, S.

Specific description.—The holotype has a length of 640 mm., of which the posterior 307 mm. is uncrushed. It has a greatest diameter of 82 mm. at the anterior end of the uncrushed portion, and a diameter of 28 mm. at the posterior end of the incomplete specimen. The ratio of expansion of the shell is about 1 mm. in diameter for 6 mm. in length, indicating an apical angle of nine degrees.

The rate of increase in the diameter of the siphuncle is slight, the apical angle being less than four degrees. *R. fayettevillensis* differs further from *R. solidiforme* in that the nummuli are not so flattened, the ratio of the greatest width to the length being as eleven to seven. In addition the concavity of both the true and false septa is less in this species, being equal to the length of one nummulus in the case of the true septa, and the equivalent of the length of one and a half nummuli

for the false septa. The imaginary plane of separation between successive nummuli makes an angle of eighty degrees with the longitudinal axis of the siphuncle. The endosiphuncle is more prominent than in *R. solidiforme*, but the deposits in the siphuncle are less regular, and the lunettes are not conspicuous.

The fillings of the camerae are also different from those in *R. solidiforme*, although the broken material on the ventral side of the siphuncle is arranged in somewhat the same fashion. The pseudosepta are definitely anterior of the median portion of the septal chambers, and the deposits exhibit no layers built up on the septa. Instead, the stereoplasm shows no definite structure except that it is marked by a series of ray-like projections, which extend out from the pseudoseptum in each camera. In all other respects *R. fayettevillensis* is essentially the same as *R. solidiforme*, and it is doubtful if the two could be distinguished one from the other in unsectioned specimens.

A small specimen found at the same locality as the holotype exhibits a very similar internal structure and is referred to this species in spite of the slightly cyrtconic character of the shell in its early neanic stage.

Locality and horizon.—These specimens were found on Fly Creek, a tributary of the Barren Fork of Illinois River, Arkansas, in the NE. $\frac{1}{4}$ of the NE. $\frac{1}{4}$ sec. 29, T. 14 N., R. 32 W. Their exact stratigraphic position was thirty feet above the top of the Boone limestone, in the lower shale of the Fayetteville formation.

RAYONNOCERAS CADYI, sp. nov.

Plate 2, fig. 7.

Specific description.—The holotype is a badly crushed, incomplete specimen having a total length of 353 mm. The diameter at the anterior end is 105 mm. and 38 mm. at the posterior end. This would indicate an apical angle of about ten degrees, but this figure is too high owing to the fact that the flare due to flattening is greatest at the anterior end of the specimen.

The rate of enlargement of the siphuncle is very small, being but 1 mm. in diameter for 26 mm. in length. The deposits of the siphuncle are not so regular as in *R. solidiforme* but they are more uniform than in *R. fayettevillensis*. The lunettes are well developed, although they are not prominent in the longitudinal section. The endosiphuncle is large and its rayonnettes divide the nummuli distinctly above their median plane. The ratio of the width to the length of the nummuli is as thirteen to eight and the plane of their greatest diameter is orad of

the median plane. Thus they are in outline somewhat like the nummuli of *Huronia*, although the flare is not as prominent as is usual in that genus. The imaginary plane of separation of the nummuli is practically normal to the longitudinal axis of the siphuncle. The eccentricity of the siphuncle is slight.

Probably seven septa occur per diameter, but the crushed condition of the conch makes measurements uncertain. In section the septa are seen to extend straight from the siphuncle diagonally forward to the shell of the animal; they are everywhere roughly equidistant from one another, and from the pseudosepta. This feature also may be the result of the crushing of the conch, but the deposits of the camerae do not indicate that they have been disturbed. The deposits of stereoplasm are composed of uniform layers which extend straight from the pseudoseptum to the true septa and are normal to them throughout.

The sutures were plainly undulating, but the position of the lobes and saddles cannot be determined. The shell itself is unknown.

Locality and horizon.—This specimen was found at Durham, Arkansas, at the same locality and horizon which yielded the holotype of *R. solidiforme*.